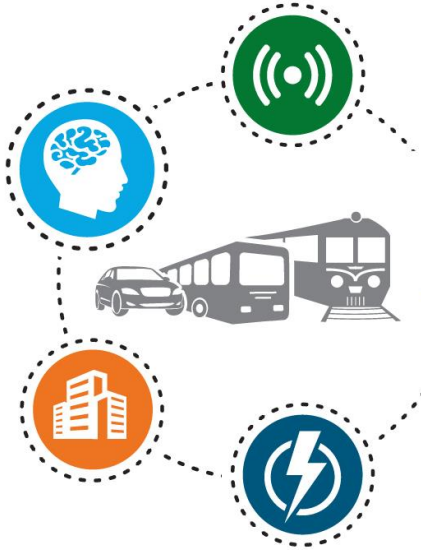
Project ID: EEMS011



U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Short and Long-run Mobility Behavior and System Energy Efficiency

Colin Sheppard, LBNL
2017 VTO Annual Merit Review
June 20, 2018

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

BERKELEY LAB

OAK RIDGE National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

ENERGY EFFICIENT MOBILITY SYSTEMS PROGRAM
INVESTIGATES

MOBILITY ENERGY PRODUCTIVITY

THROUGH FIVE EEMS ACTIVITY AREAS

Advanced R&D Projects

Living Labs

Smart Mobility Lab Consortium

HPC4Mobility & Big Transportation Data Analytics

Core Evaluation & Simulation Tools

Advanced Fueling Infrastructure

Connected & Automated Vehicles

Urban Science

SMART MOBILITY LAB

CONSORTIUM

7 labs, 30+ projects, 65 researchers,
$34M* over 3 years.

Mobility Decision Science

Multi-Modal Transport

*Based on anticipated funding

Overview

Timeline

- Start date: 10/2016
- End date: 09/2019
- Percent complete: 50%

Budget

- Total funding: $1.5M
  –DOE share: 100%
- FY 2017: $0.45M
- FY 2018: $0.5M

Barriers

- Limited understanding of system-impacts of mobility mega-trends
- Scalable modeling of future transportation system difficult
- Models need appropriate representation of behavior

Partners

- Project Lead: LBNL
- Partners: LBNL, UC Berkeley, Conveyal, NREL, ORNL

Objectives & Relevance

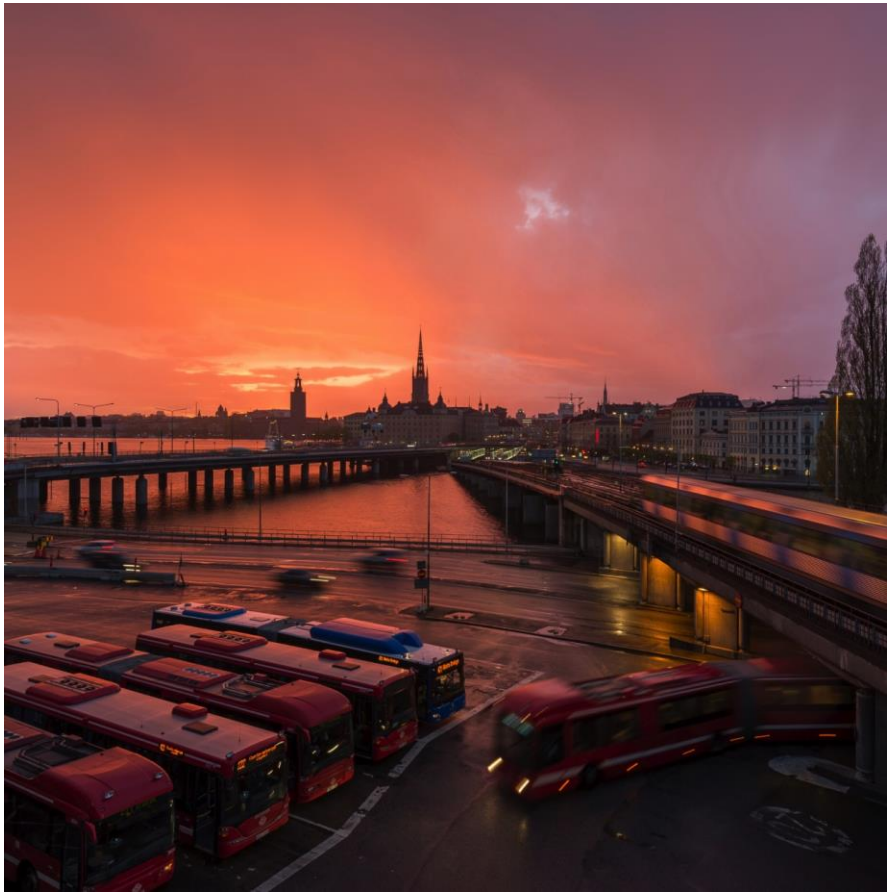
- Transportation systems becoming more dynamic, connected, and complex
- Travelers are faced with more modal options and situational awareness than ever before
- This project aims to endogenize traveler behavior in BEAM – a fully multimodal and scalable urban simulation tool – to understand the impact of behavior on regional energy outcomes
- Traveler behavior with respect to mode choice is critical to accurately assess the uptake and energy consumption of new mobility technologies. This task makes mode choice endogenous and enables analysis of both short and long-term changes to traveler preferences.
- Supports EEMs/VTO Goal: Linking long-term modality styles with short/medium term mode choice in a multimodal transportation system, with the ability to simulate emerging mobility services.

Milestones

Date	Milestone	Status
June 2017	Enable full range of multi-modal travel decision making in Agent-based transportation system models	Complete
September 2017	Early simulation model results for energy/GHG estimates for multiple MDS scenarios for SF Bay and Chicago	Complete
March 2018	Progress update presentation on behavioral model development	Complete
June 2018	Scenarios Defined for Analysis	On track
September 2018	Report on calibration results, medium-term normative study, and proof-of-concept long-term normative approach.	On track

Approach: Systems Modeling

- Enhance existing modeling capabilities to enable large-scale, agent-based simulations of multimodal urban transportation systems
- Design an extensible simulation framework that can readily accommodate new mobility modes and new insights into or models of traveler behavior
- Validate the model against existing data sources
- Conduct sensitivity analyses of mobility mega-trends



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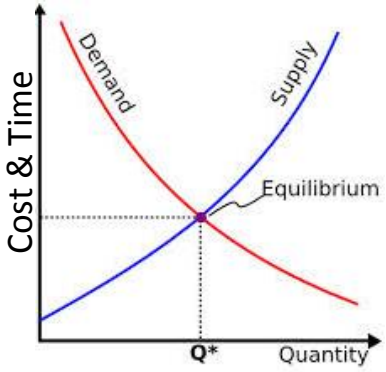
Technical Accomplishments Summary

- Continued BEAM development:
  - Drive to transit
  - Parking
  - Ride hail surge pricing
  - Ride hail redistribution
  - Vehicles as agents
  - Network traffic simulation from MATSim integration
  - Integrated R5, advanced transit router
- Implemented multiple mode choice approaches
  - Multinomial logit
  - Latent class mode choice
- Ran sensitivity studies
- Prepared data for preliminary calibration

BEAM simulates Resource Markets

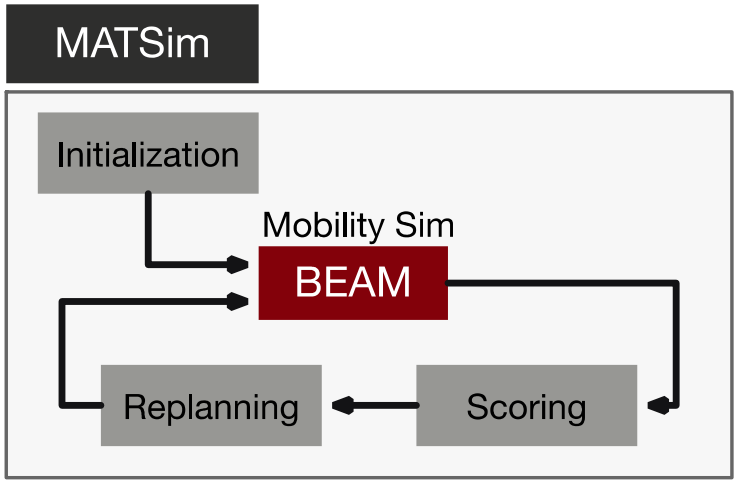
- Since AMR ’17, we added new resource markets to BEAM:
  - Road Capacity
  - Vehicle Capacity
  - Parking/Refueling Access
  - TNC Availability (enhanced previous solution)

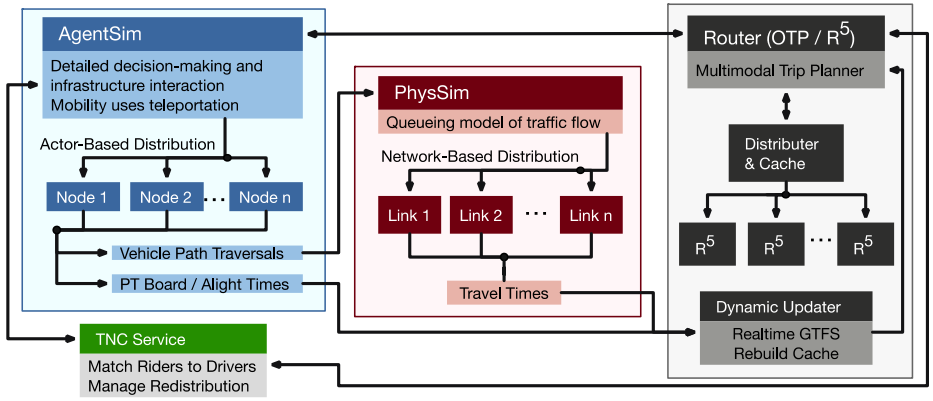


- These markets are composed of:
- Supply:
  - Driving
  - Transit
  - Intermodal (drive to transit)
  - Walk / Bike
  - TNC (centrally managed)
  - Parking
- Demand (governed by behaviors):
  - Mode Choice
    - Price & Time Sensitive
  - Route Choice
    - Multimodal
  - Rerouting
  - Parking Choice

BEAM extends MATSim

- In previous year, we began extending MATSim to allow parallelizable, within-day dynamics to occur in a transportation system composed of resource markets
- Since AMR ‘17 we completed the architecture for this transformation and have conducted multiple refactorings to make the software easier to maintain and extend

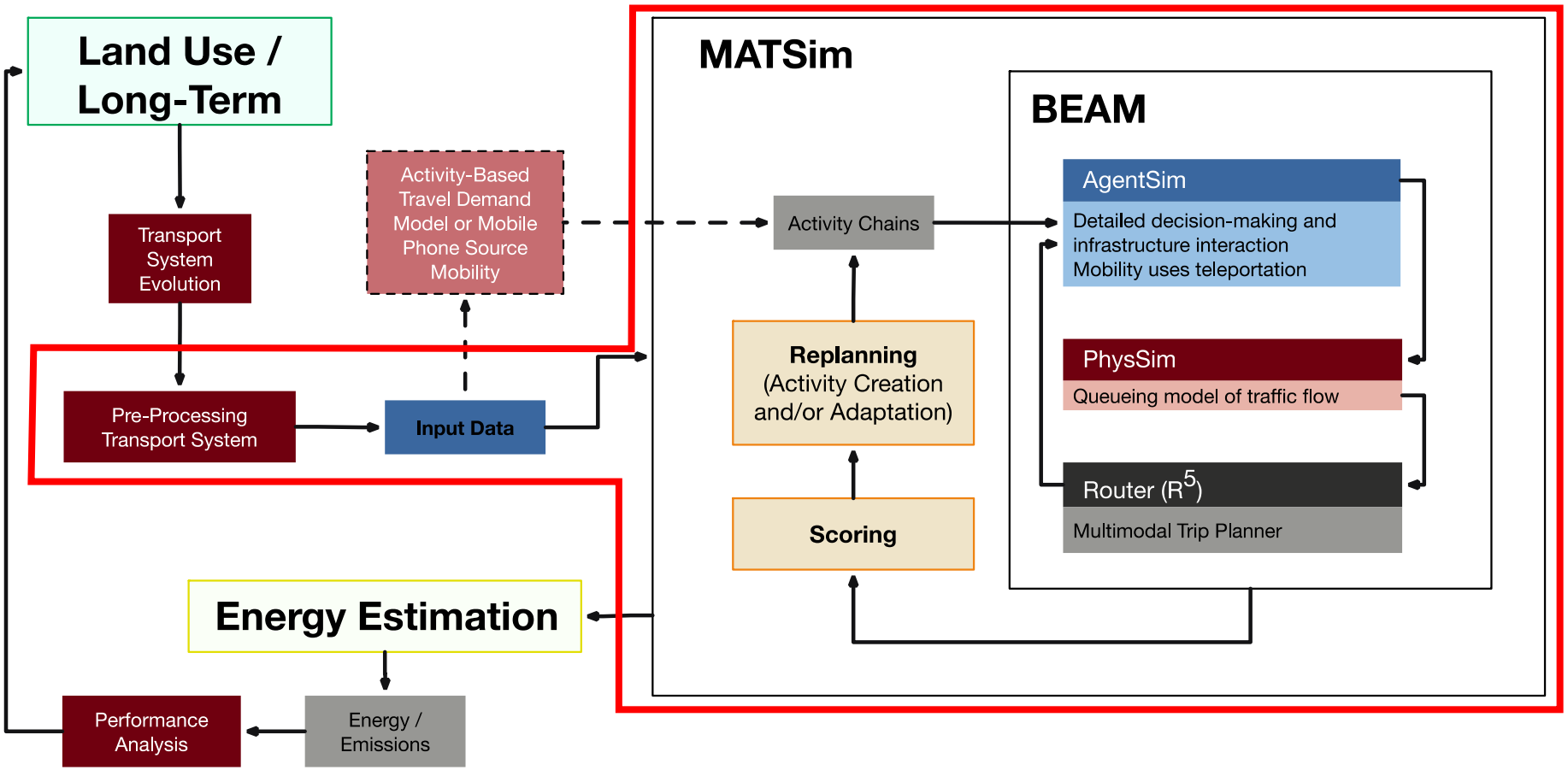




Vision for full BEAM Integration

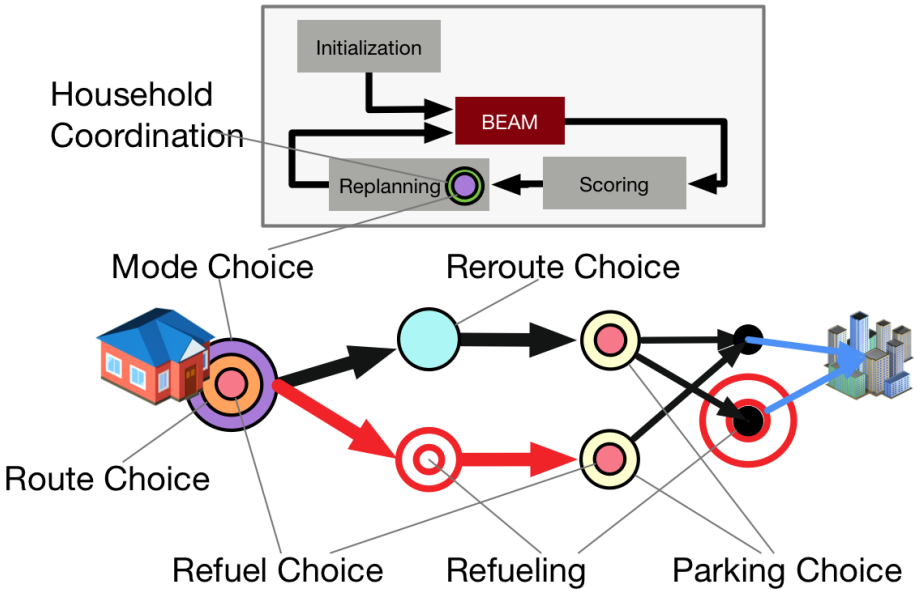
BEAM Vision

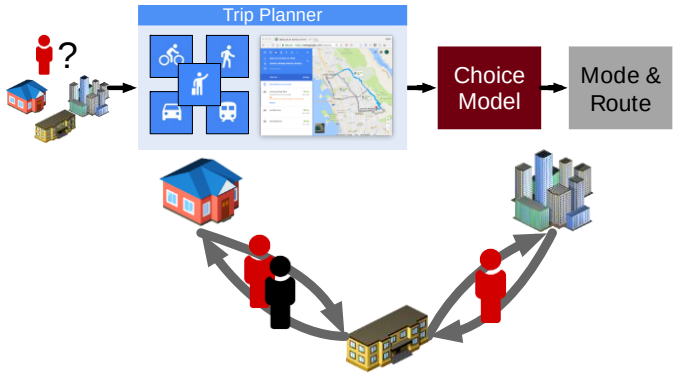
- Our plan for BEAM is to integrate with UrbanSim in FY19
- Red box is current scope



Behavioral Modeling in BEAM

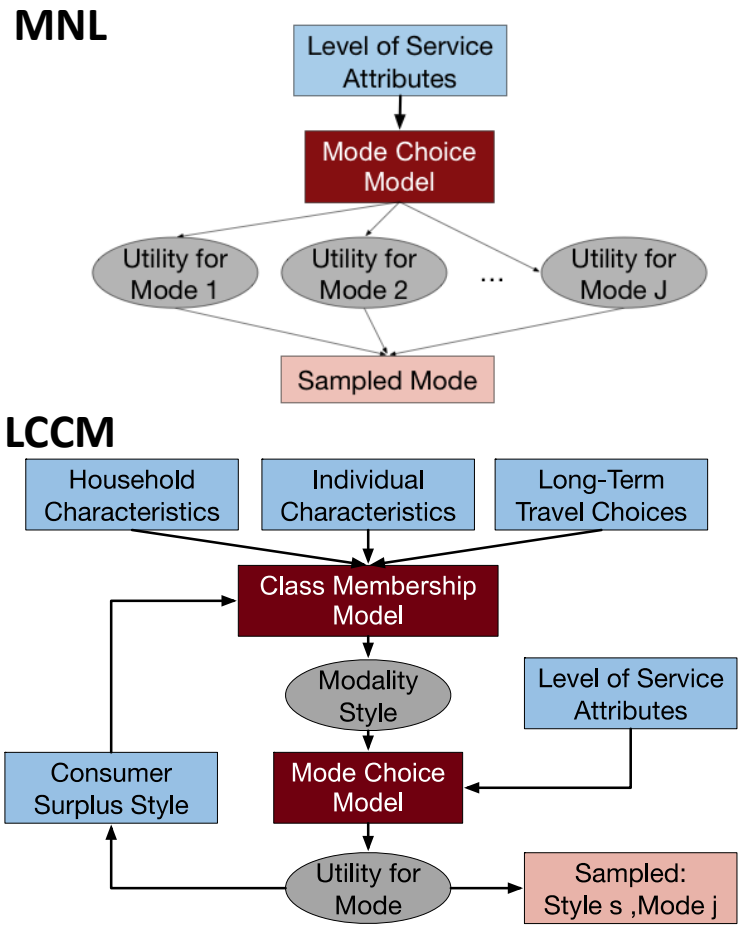
- Person agents make decisions during replanning (i.e. before the day begins) as well as throughout their day including:
  - At the point of departure: mode choice, route choice
  - During trips: rerouting, parking, and refueling (under development)
- Within-day mode choice is based on virtual trip planner that enumerates and quantifies alternative attributes, then samples from discrete choice probability distribution





Two Mode Choice Models

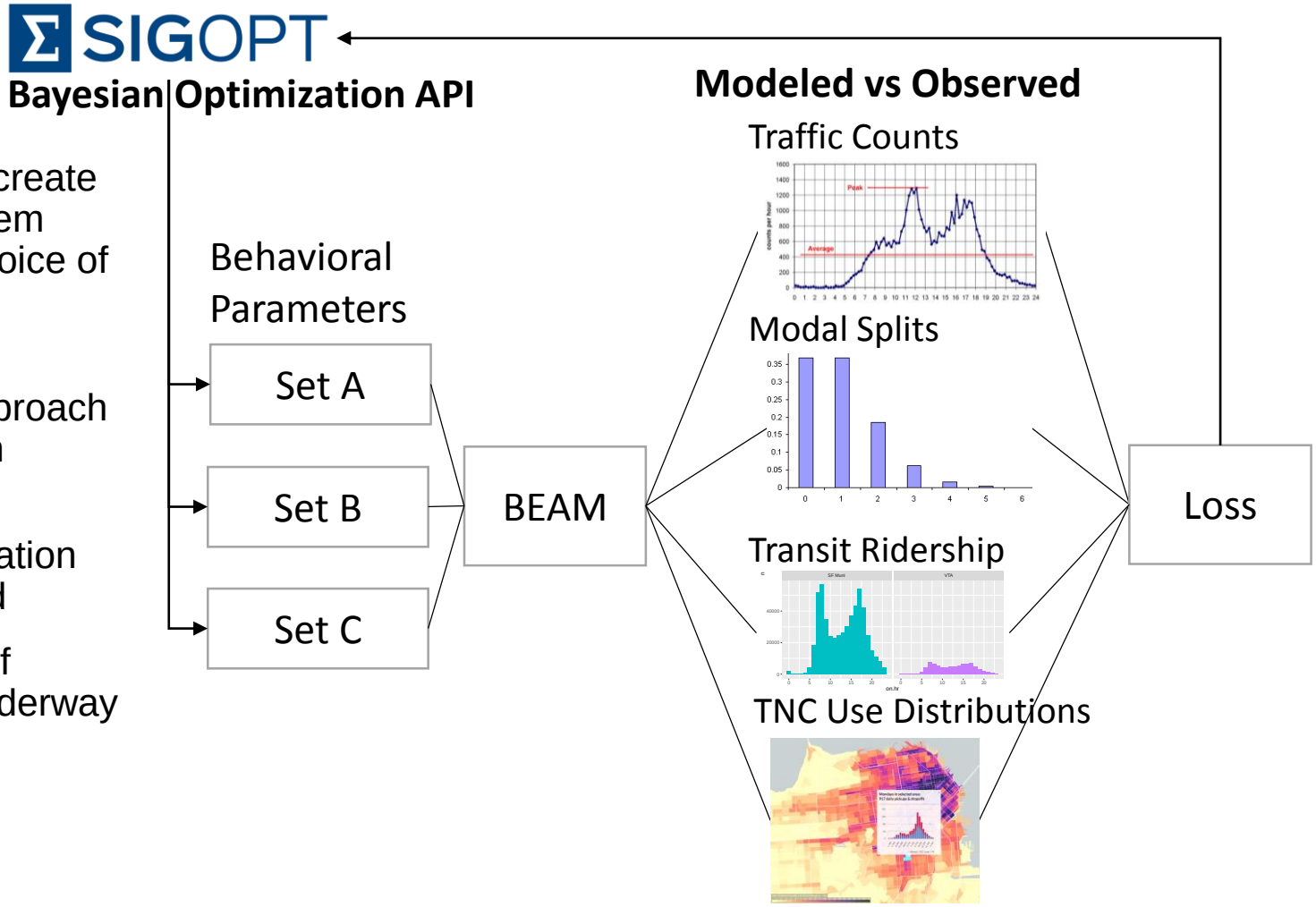
- Multinomial Logit Model (MNL) vs. Latent Class Mode Choice Model (LCCM)
- MNL captures tradeoff between cost and time with some inherent preferences for modes (used for tuning)
- LCCM is a two-stage model:
  - Class Membership
  - Mode Choice
- Modality style a function of consumer surplus, which summarizes system level of service



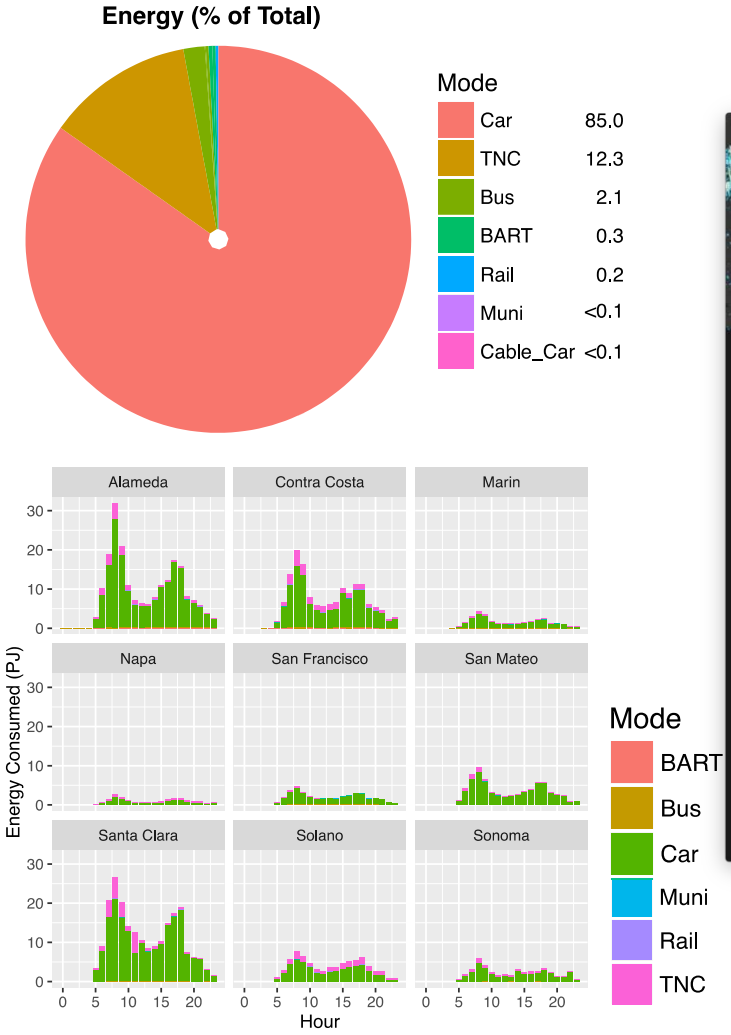
Adapted from Vij et al. (2017)

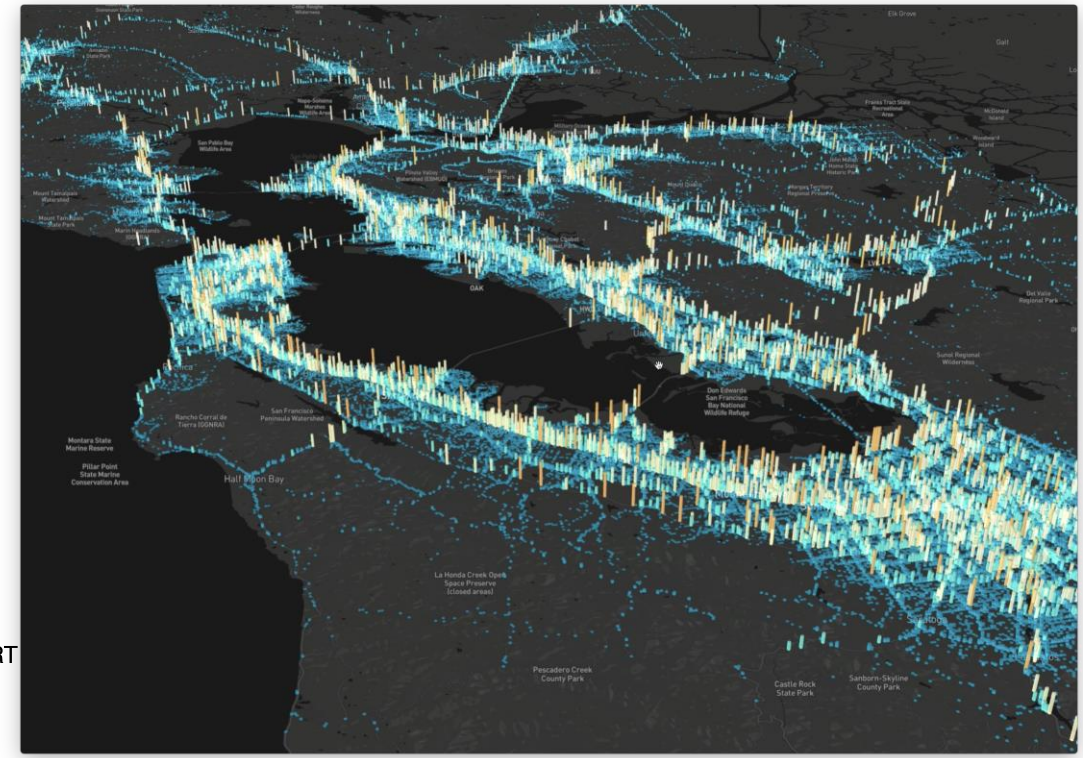
Calibration Plan

- We seek to recreate observed system patterns by choice of behavioral parameters
- Calibration approach uses Bayesian optimization
- Data for calibration are assembled
- Initial testing of workflow is underway

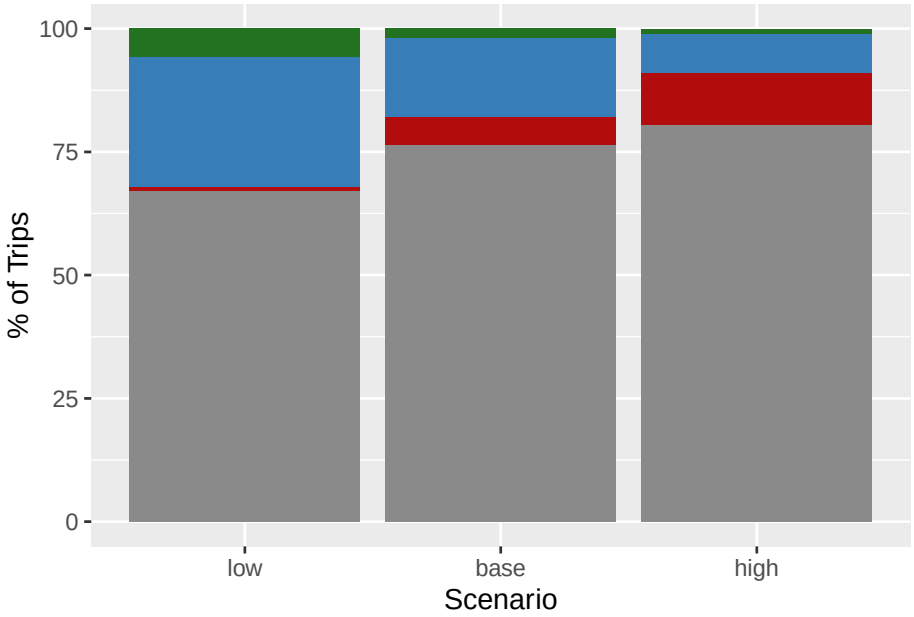


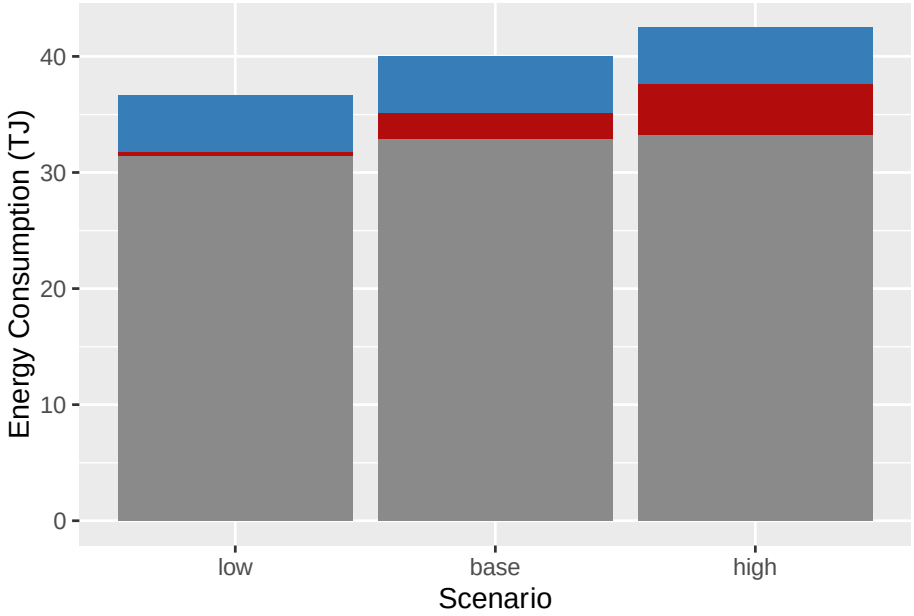
Slicing SF Bay Daily Energy Consumption





Impact of Value of Time





- Using multinomial logit choice model
- Large change in split driven by VOT changes
- Argues for VOT heterogeneity

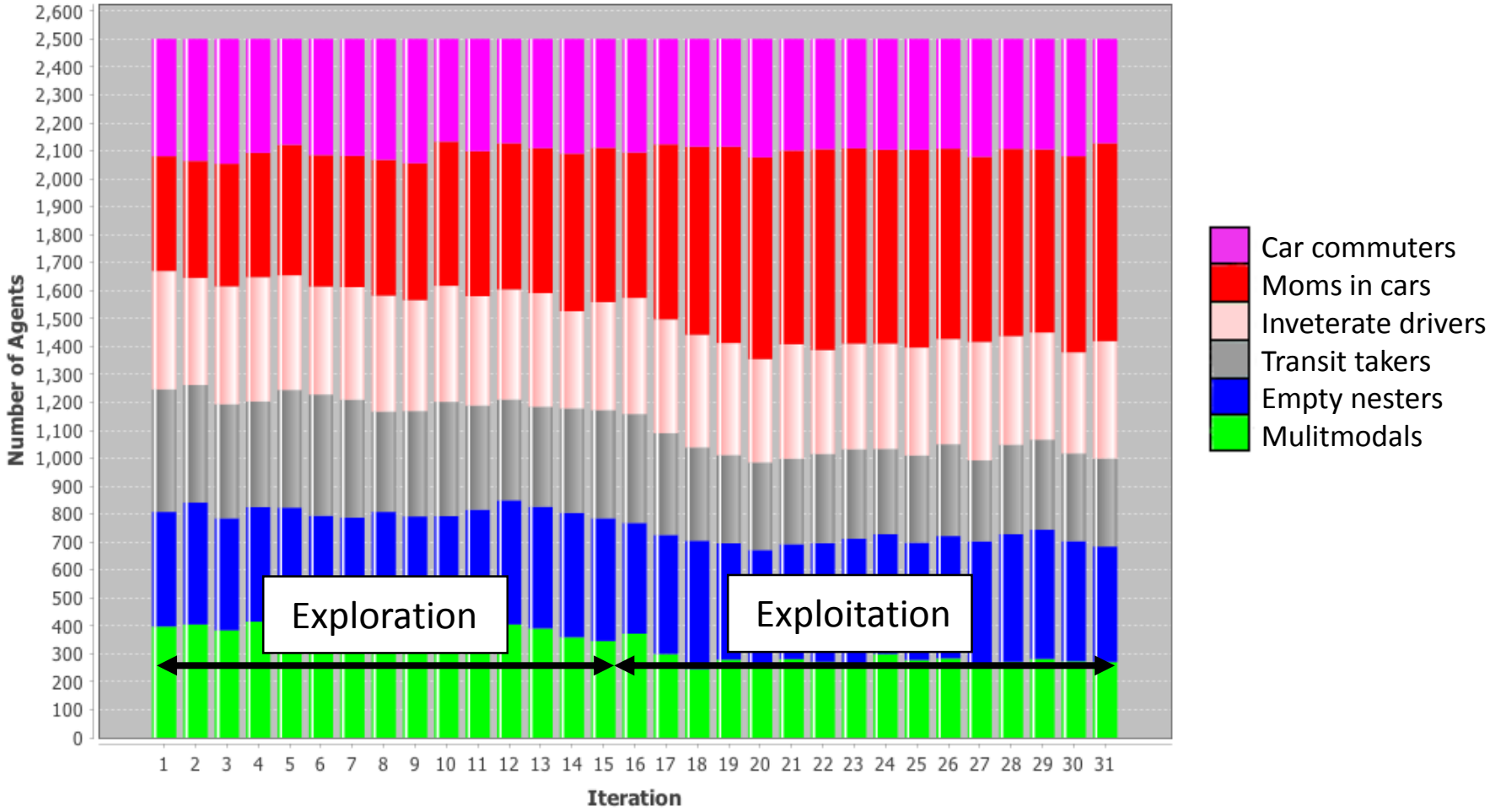
Scenarios:

- Low $8.5/hr
- Base $16.9/hr
- High $25.4/hr

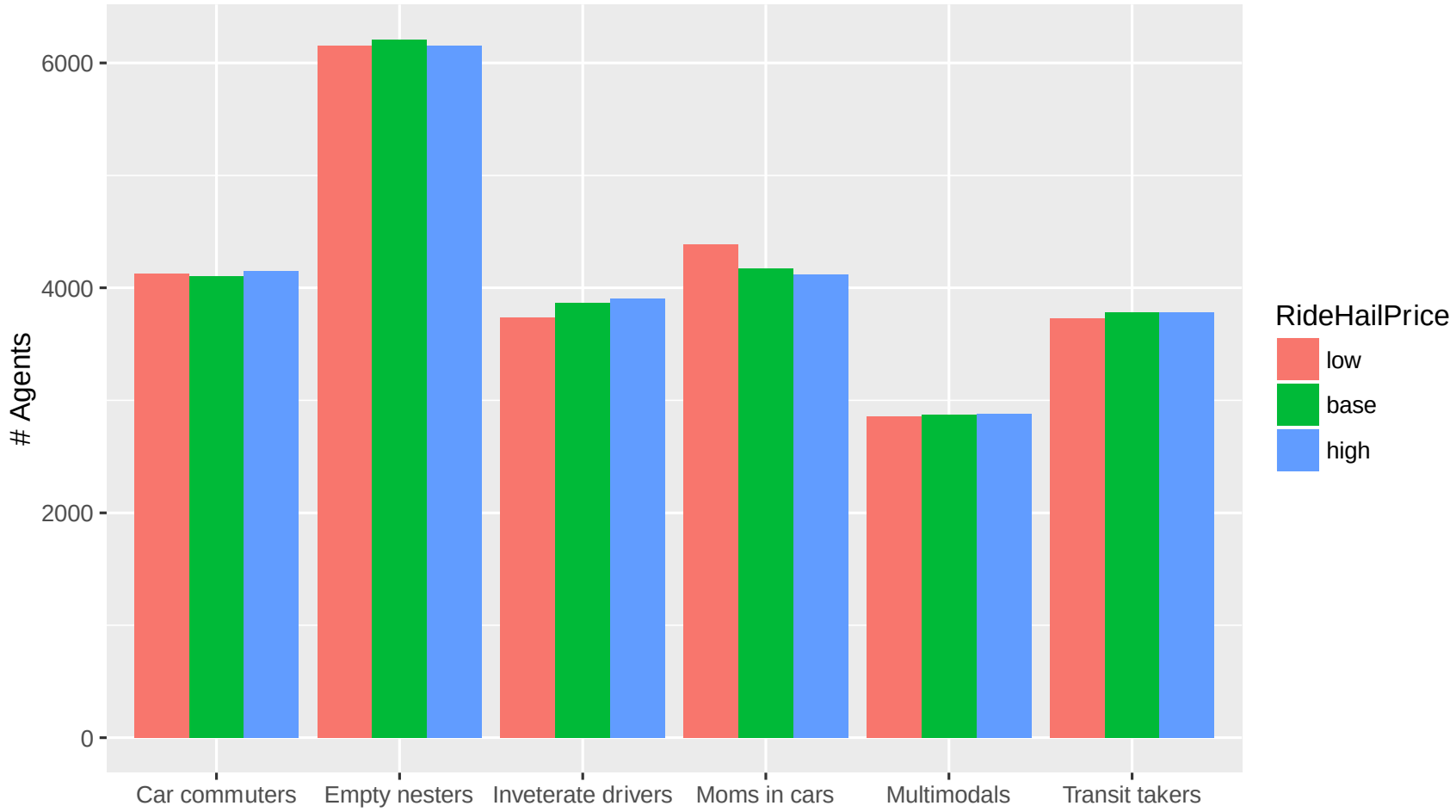
Trip Mode

- Car
- TNC
- Transit
- Walk

Modality Style Convergence



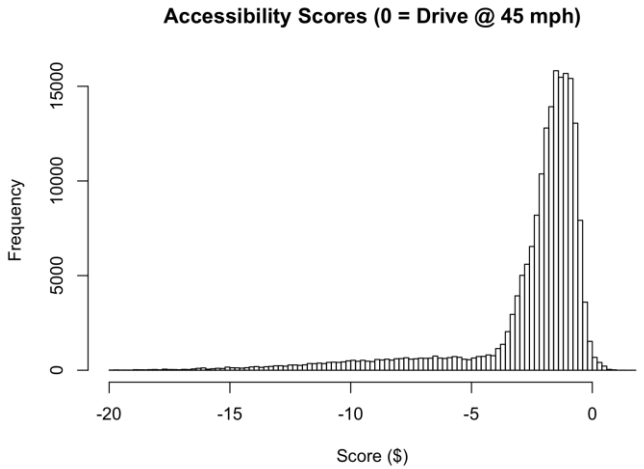
Modality Style Sensitivity

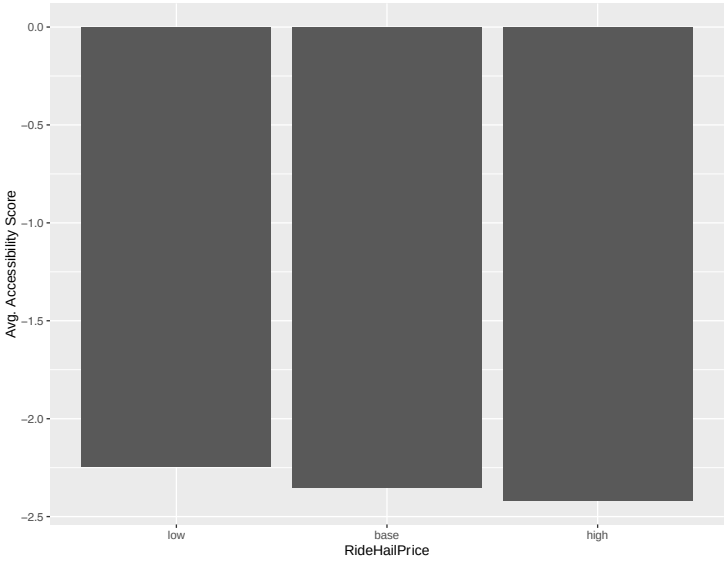


Accessibility Measure

- Disutility of your choice set minus the disutility of a set that includes only driving at a constant speed of 45mph.
- E.g. a choice set of walking-only that takes one hour longer than driving at 45mph with $10/hr value of time, would score -10.
- Because accessibility is influenced both by cost and time, decreasing ride hailing price increases system accessibility

$$S = log\left(\sum_j e^{V_j}\right) - log\left(e^{V_{car}}\right)$$





Responses to FY17 Reviewers

The reviewer noted that understanding the adaptive nature of the transportation system, for example, TNC supply-demand matching, and modeling not just individuals, will support intelligent interventions once the model is robust enough and accessible enough to use locally.

We completely agree and have increased the sophistication of the TNC module since AMR '17 including adding surge pricing, vehicle redistribution, and developing an API for third party control algorithm developers to control the TNC fleet within BEAM.

The reviewer mentioned that overall the approach looks good, but there are specific aspects that need clarification, specifically, the scheduler apparently is allowed to relax strict chronology in order to achieve higher computation speeds. The reviewer noted that it is not clear if this will result in an agent missing the bus or the plane. The reviewer also wondered if the scheduler will also ensure that the agent does not miss a plane by delaying the plane. However unlikely, it was not clear from the explanation how this aspect is addressed.

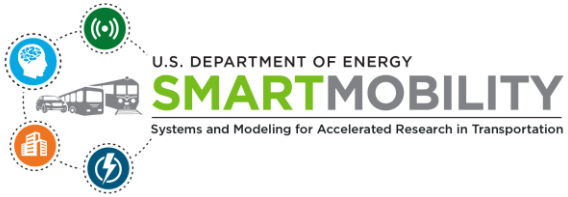
An excellent observation. We have solved this particular problem by allowing agents to board transit vehicles "in hindsight". Even if a transit vehicle has processed its departure from a stop, a person can be added to the vehicle (within the scheduler window) as long as the vehicle has space and hasn't reached the next stop. This produces no logical inconsistencies and prevents spurious "missing the bus" issues.

Collaborations

- Advising mode choice model specification

- Authors of open source R5 multimodal routing software
- Assisting with integration of router into BEAM

- Developing ride hailing fleet optimization schemes for customer matching, rebalancing, and EV charging to deploy within BEAM



- NREL & ORNL: Vehicle adoption forecasts and reduced form vehicle energy model

Remaining Challenges

- BEAM focus is on enabling flexible modeling of traveler behavior, but team will rely on SMART collaborators – particularly results from Whole Traveler task – to finalize plausible models to test
- Also focus on enabling a test bed for operations research in mobility services design, but team will rely on collaborators to provide scalable algorithms
- More work required to distribute routing calculations and optimize balance between computation versus caching

Remaining Work

FY18 Remaining Work

- Complete initial calibration for San Francisco Bay Area
- Complete two key model features:
  - Ride hailing fleet rebalancing
  - Ride hailing as access and egress mode in transit trips
- Plan connection between Whole Traveler Behavioral Study findings with BEAM:
  - Enable evolution of modal preferences based on projected demographics
  - Enable evolution of modal preferences based on observed historical trends in WT results

FY19 Future Work

- Integrate model of long-term modal behavioral patterns from Whole Traveler Behavioral Study
- Conduct impact assessments, e.g.:
  - Impact of large scale TNC deployment on energy
  - Test opportunities for energy efficient mode shifting
  - Impact of empty vehicle movements and mitigation strategies
  - Explore dependency between electrification, infrastructure, and mobility mega-trends

ANY PROPOSED FUTURE WORK IS SUBJECT TO CHANGE BASED ON FUNDING LEVELS

Summary

- Emerging transportation system is complex and evaluating the impact of emerging technologies in isolation can be problematic
- Agent-based models enable whole systems approach to assess impacts of transportation mega-trends
- Rich models of traveler choice can enhance realism of our simulation studies and yield insight into the how mobility preferences may change in the future

Credit: https://commons.wikimedia.org/wiki/File:Liding%C3%B6bron_October_2015_03.jpg
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QUESTIONS?

Technical Back-Up Slides

Scenarios used for Illustrative Results

- San Francisco Only Scenario
  - 3% Sample (25k person, 26k vehicles, 500 TNC fleet, Muni + BART)

- Full Bay Area Scenario
  - 5% Sample (~400k persons, 340k cars)
  - Full Transit (27 agencies, 828 routes)
  - TNC Fleet (20,000 - also referred to as Ride Hailing)